CLAIMS

1. Apparatus for generating an optical sub-carrier multiplexed signal, comprising

a digital signal processor having a plurality of electrical inputs, in use each receiving an input signal representing data to be carried on a sub-carrier of the optical sub-carrier multiplexed signal, and an electrical output outputting an output signal, and

a modulator having an electrical input, in use receiving the output signal from the digital signal processor, and an optical output, in use outputting the optical sub-carrier multiplexed signal,

wherein the output signal of the digital signal processor is the result of a Fourier transform performed on the input signals.

2. Apparatus according to claim 1 where the spacing of the sub-carriers in the sub-carrier multiplexed signal is substantially equal to an integer multiple of 1/(Symbol period).

3. Apparatus according to claim 1 further comprising a mapper having an electrical input, in use receiving binary data, and a plurality of electrical outputs connected to the electrical inputs of the digital signal processor, wherein the signals carried by the outputs are a representation of the binary data according to a predetermined modulation format.

4. Apparatus according to claim 3 where the predetermined modulation format is a phase modulation format.

5. Apparatus according to claim 3 where the predetermined modulation format is a differential phase modulation format.

6. Apparatus according to claim 3 where the predetermined modulation format is an amplitude modulation format.

7. Apparatus according to claim 3 where the predeteremined modulation format is an amplitude and phase modulation format.

8. Apparatus according to claim 1 the digital signal processor further comprising a serialiser, having a plurality of electrical inputs connected to the electrical outputs of the digital signal processor, and an electrical output in use carrying a signal generated by the serialisation of the signals carried on the plurality of electrical inputs to the serialiser.

9. The apparatus of claim 1 further comprising a digital to analogue converter having an electrical input connected to the electrical output of the digital signal processor, and an electrical output connected to the modulator, in use the output of the digital to analogue converter being an analogue representation of the digital input signal.

10. Apparatus according to claim 1 further comprising an electrical signal generator, connected to an input of the modulator, wherein a small depth modulation is imparted on the optical sub-carrier multiplexed output signal.

11. Apparatus according to claim 1 wherein the modulator is configured to modulate the amplitude and phase of an optical carrier.

12. Apparatus according to claim 11 wherein the modulator comprises two Mach-Zehnder structures, connected to an optical combiner.

13. Apparatus according to claim 1 wherein the modulator comprises

an electrical signal modulator having an electrical signal input, in use receiving the output of the digital signal processor, an electrical carrier input in use receiving a carrier signal, wherein the carrier is modulated in response to the electrical signal input to generate a modulated electrical signal which is output on an electrical output,

an optical modulator having an optical input in use receiving an optical carrier and an electrical input connected to the output of the electrical signal modulator, wherein the optical carrier is modulated in response to the output of the electrical signal modulator.

14. Apparatus according to claim 13 wherein the optical modulator is an optical amplitude modulator.

15. Apparatus according to claim 13 wherein the optical modulator is an optical phase modulator.

16. Apparatus according to claim 1 further comprising a forward error correction coder connected to the digital signal processor, in use applying forward error correction coding to the data.

17. Apparatus for generating an optical signal consisting of a plurality of optical sub-carrier multiplexed signals, the apparatus comprising

a plurality of digital signal processors each having
a plurality of electrical inputs, in use each input receiving an input signal representing data to be carried on a sub-carrier of the optical sub-carrier multiplexed output signal, and
an electrical output carrying an output signal,

wherein, the electrical output signal of each digital signal processor is the result of a Fourier transform performed on the respective inputs of that digital signal processor,

a plurality of electrical signal modulators each having
an electrical signal input, in use receiving the output of a digital signal processor,
an electrical carrier input in use receiving a carrier signal, wherein the carrier is modulated in response to the electrical signal input to generate a modulated electrical signal, and
an electrical output outputting the modulated electrical signal,

an electrical combiner having
a plurality of electrical inputs, in use each input receiving the output of one of the electrical signal modulators, and
an electrical output in use carrying a signal generated by combining the input signals, and,

an optical modulator having

an electrical input in use receiving the output of the electrical combiner,
an optical carrier input, in use receiving an optical carrier, and
an optical output, in use outputting the plurality of optical sub-carrier multiplexed signals.

18. Apparatus according to claim 17 where the optical modulator is an optical amplitude modulator

19. Apparatus according to claim 17 where the optical modulator is an optical phase modulator.

20. An optical transmitter comprising
a digital signal processor having a plurality of electrical inputs, in use each receiving an input signal representing the data to be carried on a sub-carrier of the optical sub-carrier multiplexed signal, and an electrical output outputting an output signal, and

a modulator having an electrical input, in use receiving the output signal from the digital signal processor, and an optical output, in use outputting the optical sub-carrier multiplexed signal,

wherein the output signal of the digital signal processor is the result of a Fourier transform performed on the input signals.

21. Apparatus according to claim 20 where the spacing of the sub-carriers in the sub-carrier multiplexed signal is substantially equal to an integer multiple of 1/(Symbol period).

22. Apparatus for receiving an optical sub-carrier multiplexed signal, the apparatus comprising
an optical to electrical converter, in use receiving the optical sub-carrier multiplexed signal and outputting an electrical signal, and

a digital signal processor having an electrical input, in use receiving the output of the optical to electrical converter, and a plurality of electrical outputs, in use each carrying a

signal representing data carried on a sub-carrier of the optical sub-carrier multiplexed signal,

wherein, the outputs of the digital signal processor are the result of a Fourier transform performed on the input signal.

23. The apparatus of claim 22 further comprising a decoder having
a plurality of electrical inputs in use receiving the outputs of the digital signal processor, and
an electrical output, in use outputting binary data.

24. The apparatus of claim 23, the decoder comprising a serialiser having a plurality of inputs receiving the outputs of the digital signal processor, and an output outputting a signal derived by the serialisation of the input signals.

25. The apparatus of claim 23, the decoder comprising a threshold decoder, wherein the output data is determined by the comparison of the input signals with a predetermined value.

26. The apparatus of claim 23 wherein the decoder comprises a maximum likelihood sequence estimation decoder.

27. The apparatus of claim 22, the digital signal processor comprising

a de-serialiser having an electrical input receiving the output of the optical to electrical converter and outputting a plurality of signals obtained by the deserialisation of the input,

a Fourier transform unit having a plurality of electrical inputs, in use receiving the outputs of the de-serialiser, and a plurality of electrical outputs, in use each carrying a signal representing data carried on a sub-carrier of the optical sub-carrier multiplexed signal,

wherein the electrical outputs of the Fourier transform unit are the result of a Fourier transform performed on the inputs.

28. The apparatus of claim 22 further comprising a forward error correction decoder connected to the digital signal processor, in use performing error correction on the data.

29. The apparatus of claim 28 further comprising apparatus to determine channel state information of the sub-carriers.

30. The apparatus of claim 29 wherein the channel state information is utilised by the forward error correction decoder to improve the performance of the error correction.

31. Apparatus according to claim 22 further comprising an optical coupler, having
a plurality of optical inputs, in use one of said inputs receiving the optical sub-carrier multiplexed signal, and another of said inputs receiving the output of an optical local oscillator, and
a plurality of optical outputs, at least one of said outputs being connected to the optical to electrical converter.

32. Apparatus for receiving a plurality of optical sub-carrier multiplexed signals, the apparatus comprising an optical demultiplexer having an optical input in use receiving the plurality of optical sub-carrier multiplexed signals, and a plurality of optical outputs in use each output carrying at least one of the optical sub-carrier multiplexed signals, wherein the outputs are connected to apparatus according to claim 22.

33. Apparatus for receiving a plurality of optical sub-carrier multiplexed signals, the apparatus comprising
an optical to electrical converter having
an optical input, in use receiving the optical sub-carrier multiplexed signals, and
an electrical output in use outputting an electrical signal representative of the amplitude of the optical sub-carrier multiplexed signals,
an electrical splitter having
an electrical input, in use receiving the output of the optical to electrical converter, and
a plurality of electrical outputs, in use each outputting a predetermined fraction of the input signal,
a plurality of electrical demodulators, each having
an electrical input, in use receiving an output of the electrical splitter,

an electrical local oscillator input in use receiving an electrical signal from an electrical oscillator, and

an electrical output, in use outputting a demodulated signal,

wherein each electrical oscillator outputs a signal with a different frequency corresponding to a frequency associated with each of the plurality of sub-carrier multiplexed signals,

a plurality of digital signal processors each having

an electrical input, in use receiving the output of an electrical demodulator, and

a plurality of electrical outputs, in use each carrying a signal representing data carried on a sub-carrier of the optical sub-carrier multiplexed signals,

wherein, the outputs of each digital signal processor are the result of a Fourier transform performed on the respective input signals.

34. A receiver for use in an optical communications system comprising

an optical to electrical converter, in use receiving the optical sub-carrier multiplexed signal and outputting an electrical signal, and

a digital signal processor having an electrical input, in use receiving the output of the optical to electrical converter, and a plurality of electrical outputs, in use each carrying a signal representing data carried on a sub-carrier of the optical sub-carrier multiplexed signal,

wherein, the outputs of the digital signal processor are the result of a Fourier transform performed on the input signal.

35. A method for generating an optical sub-carrier multiplexed signal, having the steps of:

performing a Fourier transform on a plurality of signals, each signal representing data to be carried on a sub-carrier of the optical sub-carrier multiplexed signal, and

modulating an optical carrier with the signal output from the Fourier transform to generate an optical sub-carrier multiplexed signal.

36. A method according to claim 35 wherein the sub-carriers are generated with a spacing substantially equal to an integer multiple of 1/(Symbol period).

37. A method according to claim 35 further comprising the step of receiving electrical data and mapping it according to a predetermined modulation format to form the inputs to the Fourier transform.

38. A method according to claim 35, further comprising the step of applying forward error correction to the data.

39. A method according to claim 35 further comprising the step of serialising the output signals of the Fourier transform.

40. A method for receiving an optical sub-carrier multiplexed signal, having the steps of:

converting the optical signal to an electrical signal, and

performing a Fourier transform on the electrical signal to obtain a plurality of electrical signals, each signal representing the data carried on one of the sub-carriers of the optical sub-carrier multiplexed signal.

41. A method according to claim 40, further comprising the step of serialising the signals output from the Fourier transform to obtain a substantially serial data stream.

42. A method according to claim 40, further comprising the step of decoding the output signals of the Fourier transform according to a threshold decision rule.

43. A method according to claim 40, further comprising the step of applying maximum likelihood sequence estimation to the outputs of the Fourier transform.

44. A method according to claim 43, further comprising the step of decoding forward error correction applied to the data.

45. A method according to claim 44, further comprising the step of obtaining channel state information on the sub-carriers, indicative of the quality of each sub-carrier.

46. A method according to claim 45, further comprising the step of utilising said channel state information to control the behaviour of the forward error correction.

47. A method of optical communication utilising an optical sub-carrier multiplexed signal, having the steps of
performing a Fourier transform on a plurality of signals, each signal representing data to be carried on a sub-carrier of the optical sub-carrier multiplexed signal,
modulating an optical carrier with the signal output from the Fourier transform to generate an optical sub-carrier multiplexed signal,
transmitting the optical sub-carrier multiplexed signal from one location to a second remote location,
converting the optical sub-carrier multiplexed signal to an electrical signal, and
performing a Fourier transform on the electrical signal to obtain a plurality of electrical signals, each signal representing the data carried on one of the sub-carriers of the optical sub-carrier multiplexed signal.

48. An optical signal carrying data, having a plurality of sub-carriers spaced at an integer multiple of 1/(Symbol period).

49. A transmitter comprising a digital signal processor coupled to an optical signal generator, the transmitter being arranged, in use, to generate an optical data signal having a plurality of sub-carriers.

50. A transmitter according to claim 49 wherein the optical data signal is an orthogonal frequency division multiplexed signal.

51. A method of generating an optical data signal having a plurality of sub-carriers, having the steps of:
receiving an electrical data signal,
processing the electrical data in a digital signal processor, and
generating an optical sub-carrier multiplexed signal according to the output of the digital signal processor.

52. A method according to claim 51 wherein the optical data signal is an orthogonal frequency division multiplexed optical signal.

53. A receiver comprising an optical to electrical converter coupled to a digital signal processor, the receiver being arranged, in use, to receive an optical data signal having a plurality of sub-carriers.

54. A receiver according to claim 53 wherein the optical data signal is an orthogonal frequency division multiplexed signal.

55. A method of receiving an optical data signal having a plurality of sub-carriers, having the steps of:
converting the optical data signal to an electrical signal, and
processing the electrical signal in a digital signal processor.

56. A method according to claim 55 wherein the optical data signal is an orthogonal frequency division multiplexed optical signal.

57. An optical communications system comprising an apparatus, transmitter or receiver according to any one of claims 1, 18, 21, 23, 36, 35, 53 or 55.

58. An optical communications system comprising a transmitter and a receiver, in use the transmitter transmitting an optical data signal to the receiver, wherein the optical data signal is an orthogonal frequency division multiplexed signal.

59. Software for carrying out the method of any one of claims 37, 43, 51, 55 or 59.